



Wind Generation Forecasting: Status and Prospects for Improving System Integration

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Wind Generation Impacts

- ◆ Wind is an energy source
- ◆ Power system is operated in a capacity framework
- ◆ Issues
 - Increase in net load variability (minutes, hours, days)
 - Increase in net load uncertainty (day ahead, hour or hours ahead)
 - Increase in energy uncertainty over a period
- ◆ System concerns
 - Cost
 - Reliability

What is “Integration Cost”?

- ◆ From cost-based perspective
 - Increased cost of serving load not served by wind
 - Determined by comparing wind to equivalent energy source that imposes no incremental burden on operations
- ◆ Elements
 - Conventional ancillary services – regulation, etc.
 - Increased costs due to variability of wind generation
 - Increased costs due to increased uncertainty in unit commitment

UWIG Survey of Integration Studies – ca. 2003

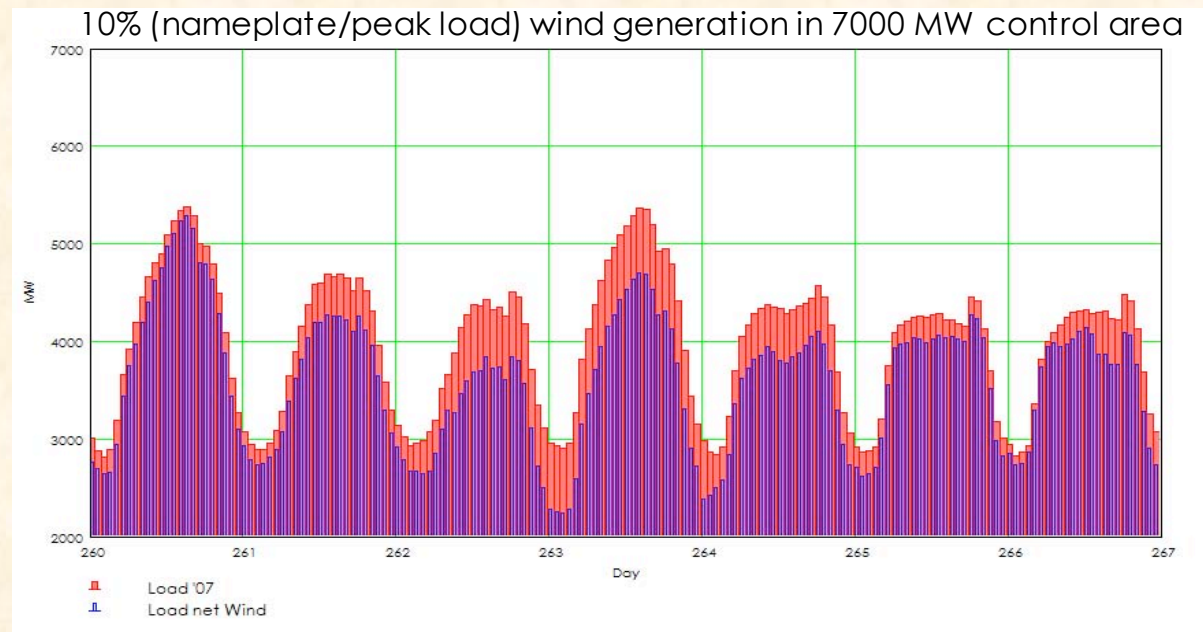
- ◆ Different assumptions, methods, and system characteristics complicates direct comparisons of results
- ◆ General view is that integration costs are modest for lower penetrations of wind generation (up to 15 or 20%)

Study	Relative Wind Penetration (%)	\$/MWh			
		Regulation	Load Following	Unit Commitment	Total
UWIG/Xcel	3.5	0	0.41	1.44	1.85
PacifiCorp	20	0	2.50	3.00	5.50
BPA	7	0.19	0.28	1.00 - 1.80	1.47 - 2.27
Hirst	0.06 - 0.12	0.05 - 0.30	0.70 - 2.80	na	na
We Energies I	4	1.12	0.09	0.69	1.90
We Energies II	29	1.02	0.15	1.75	2.92
Great River I	4.3				3.19
Great River II	16.6				4.53
CA RPS Phase I	4	0.17	na	na	na

Smith, J.C., et. al. "Wind Power Impacts on Electric Power System Operating Costs: Summary and Perspective on Work to Date" presented at the AWEA Global WindPower Conference, March 28-31, Chicago, Illinois

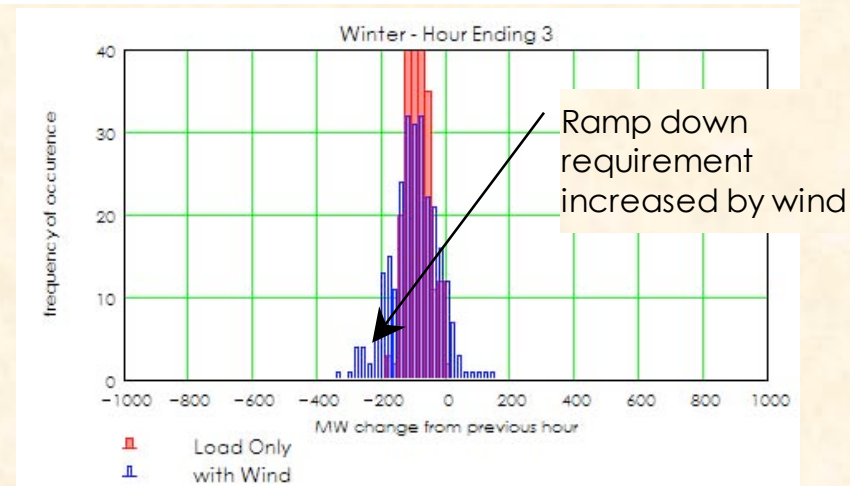
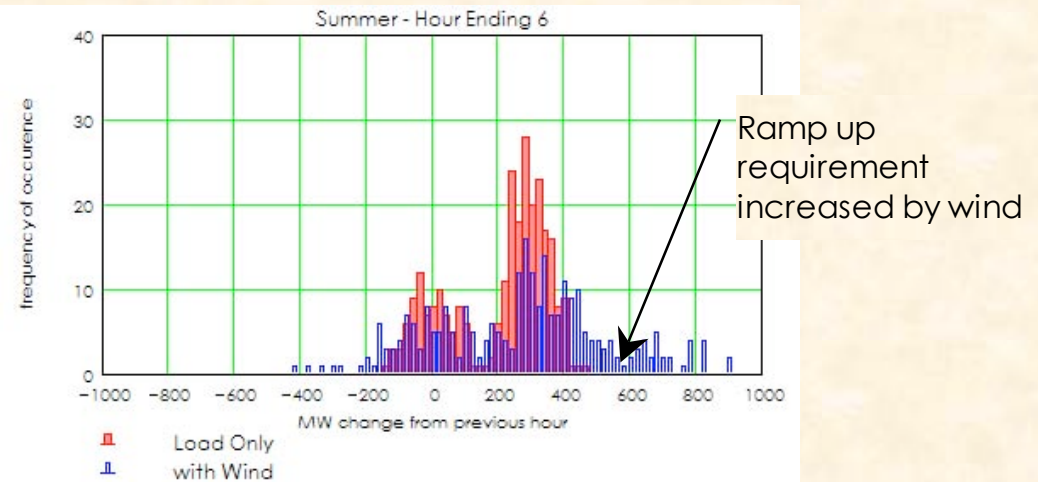
Operating the Power System with Significant Wind Generation

- ◆ Large amounts of wind can substantially alter the familiar “patterns” to which we are accustomed
- ◆ Effective wind penetration can be very high certain periods of the year



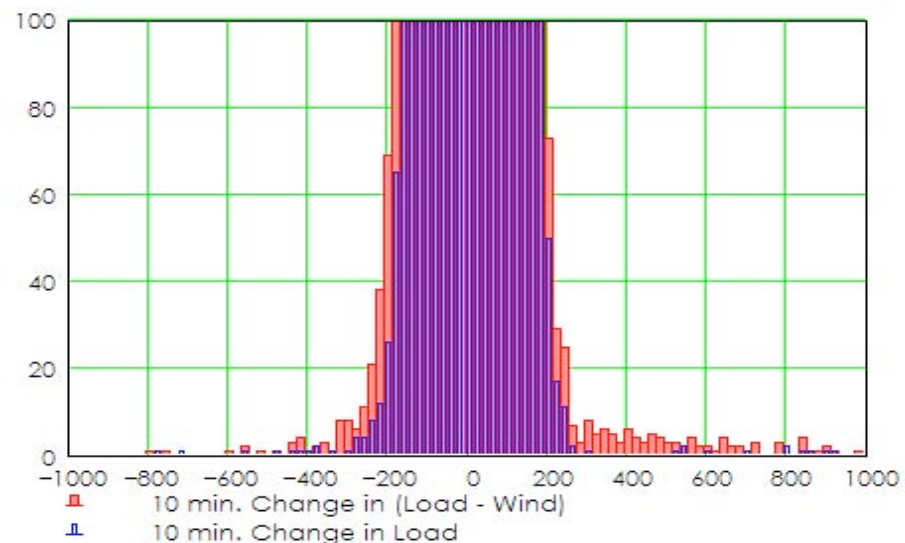
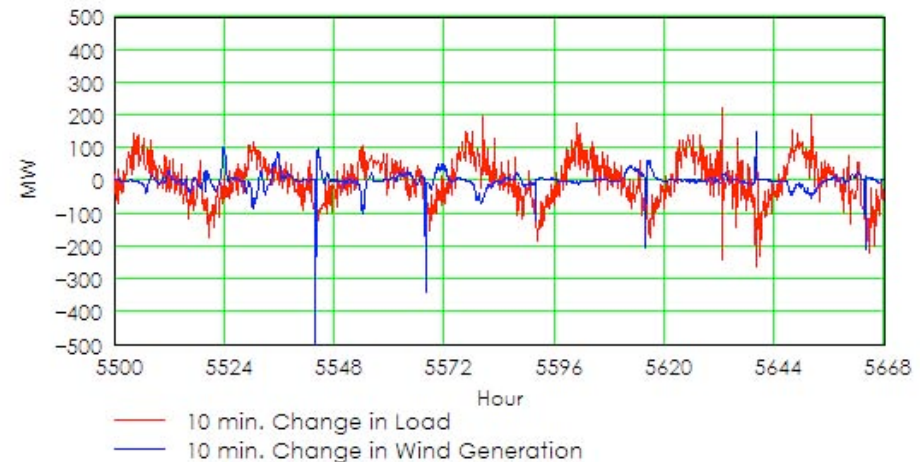
Variability of Control Area Demand

- ♦ Wind generation variability (hour to hour) may also be significant compared to load changes
- ♦ Generation must be made available to meet both planned and actual changes in control area load



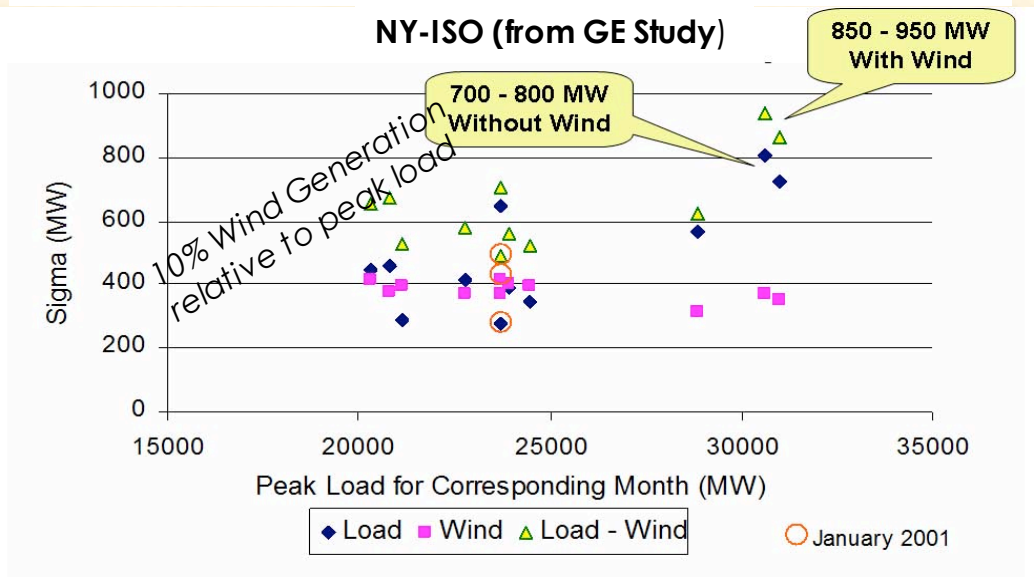
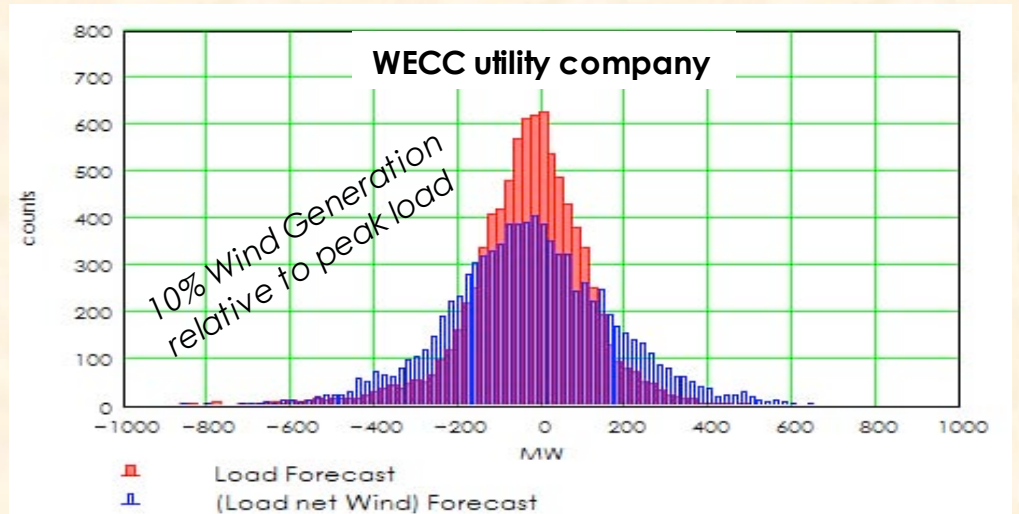
Impacts within the Hour

- ◆ Question: Does wind make control area demand more variable within the hour?
 - beyond regulation time from
 - “granularity” finer than hourly
- ◆ Question: If so, what are the economic or technical consequences?
- ◆ Thoughts to date
 - Diversity reduces demands for regulation, intra-hourly balancing
 - Impacts appear to be very modest for systems studied to date



Next-Day Uncertainty with Wind Generation

- ◆ Current forecasting technology can provide 15% MAE for next-day planning (18 – 42 hours ahead)
- ◆ Hourly errors can be significant
 - Missed timing of frontal passages
 - Hard-to-forecast patterns
- ◆ Relative to Load Forecast uncertainty
 - Wind generation may be same order of magnitude, but weakly correlated
 - Net effect on uncertainty is diminished



Market Impacts

- ◆ Wind generation forecasting shown to be beneficial for power markets
- ◆ Without forecasting, market players act on bad information

Unit Commitment

↔ \$ 95M ↔

Forecasting Value

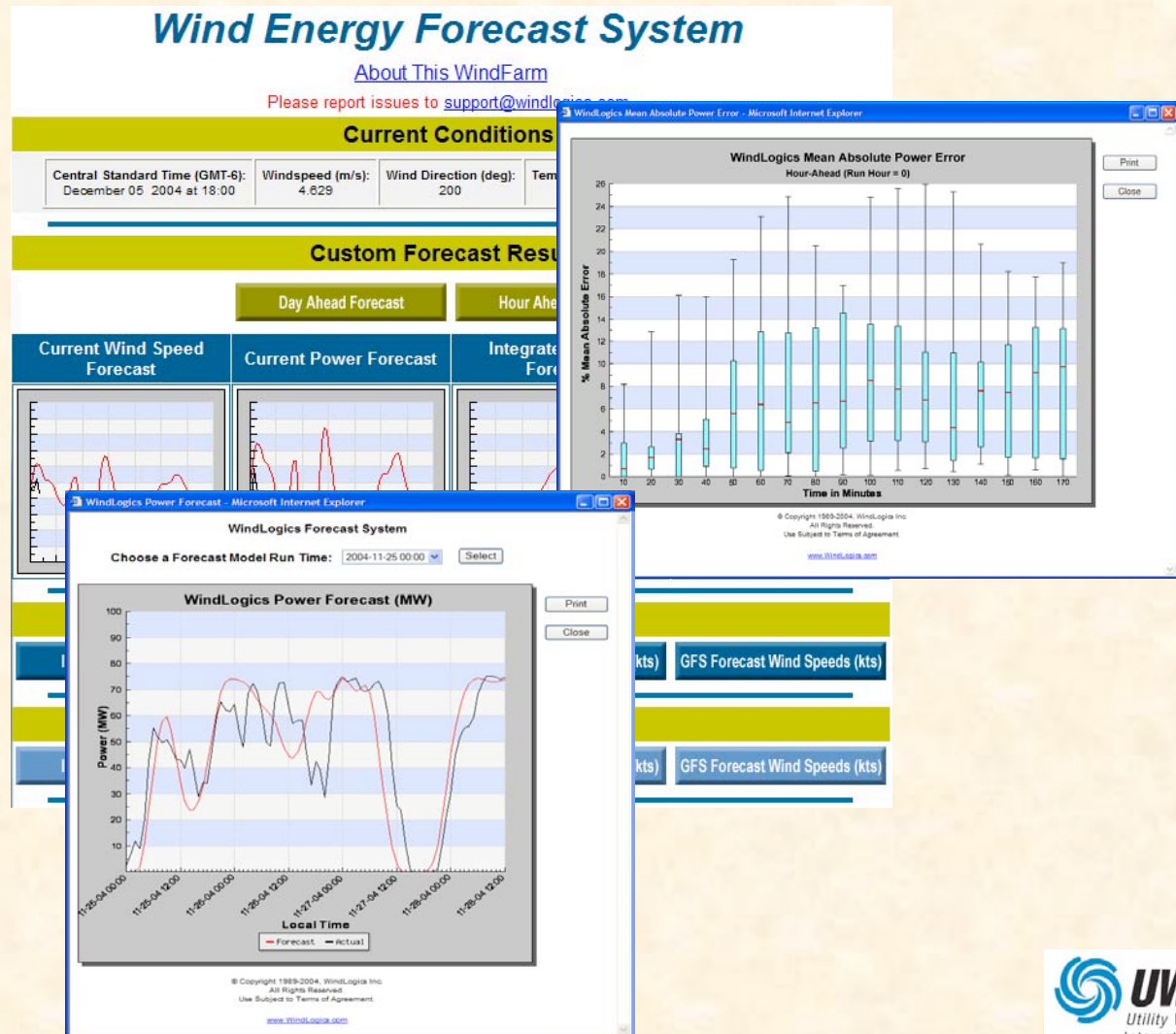
- ◆ Benefits for System Integration
 - Ancillary service cost impact for wind integration
 - Transmission congestion and scheduling
 - Forecast uncertainty is major cost component (irrespective of wind variability)
 - Forecast value grows with increasing wind on grid
- ◆ Benefits to wind plant operators
 - Depends on agreements, penalties, etc.
- ◆ Merchant power strategies & trading
- ◆ Regional differences in power and transmission systems make things interesting...
- ◆ Status:
 - Developing stages
 - Many questions about how/who/where

Insights & Perspectives: Forecasting

- ◆ Recognized as critical, but many questions remain
 - Individual plant vs. centralized forecast?
 - Use of forecast information: as delivered, or should some “hedge” factor be applied when scheduling resources?
 - How can short-term wind generation forecasts (hour or hours ahead) be used to assist with integration of large amounts of wind generation?
 - How might next-day wind generation energy production forecasts be used?
 - Would new algorithms or solution approaches for the unit commitment problem with substantial wind generation produce better results?

State of the (commercial) Art in Wind Generation Forecasting

- ◆ Many systems have demonstrated value
- ◆ Grid-side applications and expectations not established



Focus on Wind Generation Forecasting: Xcel Energy RDF Project

- ◆ Project Elements
 - “User” requirements for BA-wide wind generation forecasting system
 - Forecast “products”
 - » Day ahead forecasting for power trading
 - » Short-term forecasting for operations cost reduction, reliability enhancement
 - » “Warning” system for unusual events
 - R&D on operating strategies, utilization of wind generation forecast data, value
 - Improved algorithms for unit commitment, short-term scheduling, reliability assessment
- ◆ First project to formally address some important current questions
 - Benefits of “central” vs. “individual” wind plant forecasts
 - Value of real-time meteorological modeling, enhanced observational data

Summary: Wind Integration Costs from North American Studies

- ◆ A number of studies conducted over past five years
- ◆ More in progress
- ◆ Findings
 - Total integration costs for modest penetrations of wind generation (to 15 or 20%) range from a couple to \$5/MWH of delivered wind energy
 - Costs due to planning uncertainty and multi-hour variability seem to be most significant
 - Regulation costs are small
- ◆ Much work remains
 - Forecasting impact/value
 - Sensitivity of integration costs to resource portfolio, operating practices
 - Market impacts/structure
 - Enhanced algorithms for planning with higher uncertainty
 - Use of short-term forecast information in RT operations

Ongoing Wind Integration Studies and Assessments

- ◆ Assessment of **Integration** questions also continues in the form of specific, focused studies, e.g.:
 - Xcel Energy – Minnesota (integration cost study)
 - Xcel Energy - Colorado (integration cost study)
 - State of Minnesota (Dept. of Commerce)/Xcel RDF
 - Sacramento Municipal Utility District (prospective integration study)
 - HELCO and MECO (Hawaii)
 - Public Service New Mexico
 - BPA
 - Manitoba Hydro (integration study)
 - AESO (wind generation market impact assessment)
- ◆ Wind generation forecasting is an important element of each
- ◆ Much activity underway; difficult to track

UWIG Role in Wind Integration

- ◆ Wind generation moving forward quickly
 - Power industry forums (e.g. IEEE PES) playing catchup
 - UWIG working to bridge gap
- ◆ UWIG providing a forum for keeping abreast of developments
 - Presentation and discussion of results, methods, data
 - Focused activities in user groups
 - Special topic workshops (e.g. forecasting, transmission issues, control area operating issues, interconnection)
- ◆ Technical review for collaborative projects
 - Xcel-MN DOC
 - Xcel-PSCo.
 - Xcel RDF
 - SMUD
- ◆ Next meeting in Sacramento (Fall, 2005)